Appendix J2

Hydrostratigraphy of the Edwards and Trinity Aquifers

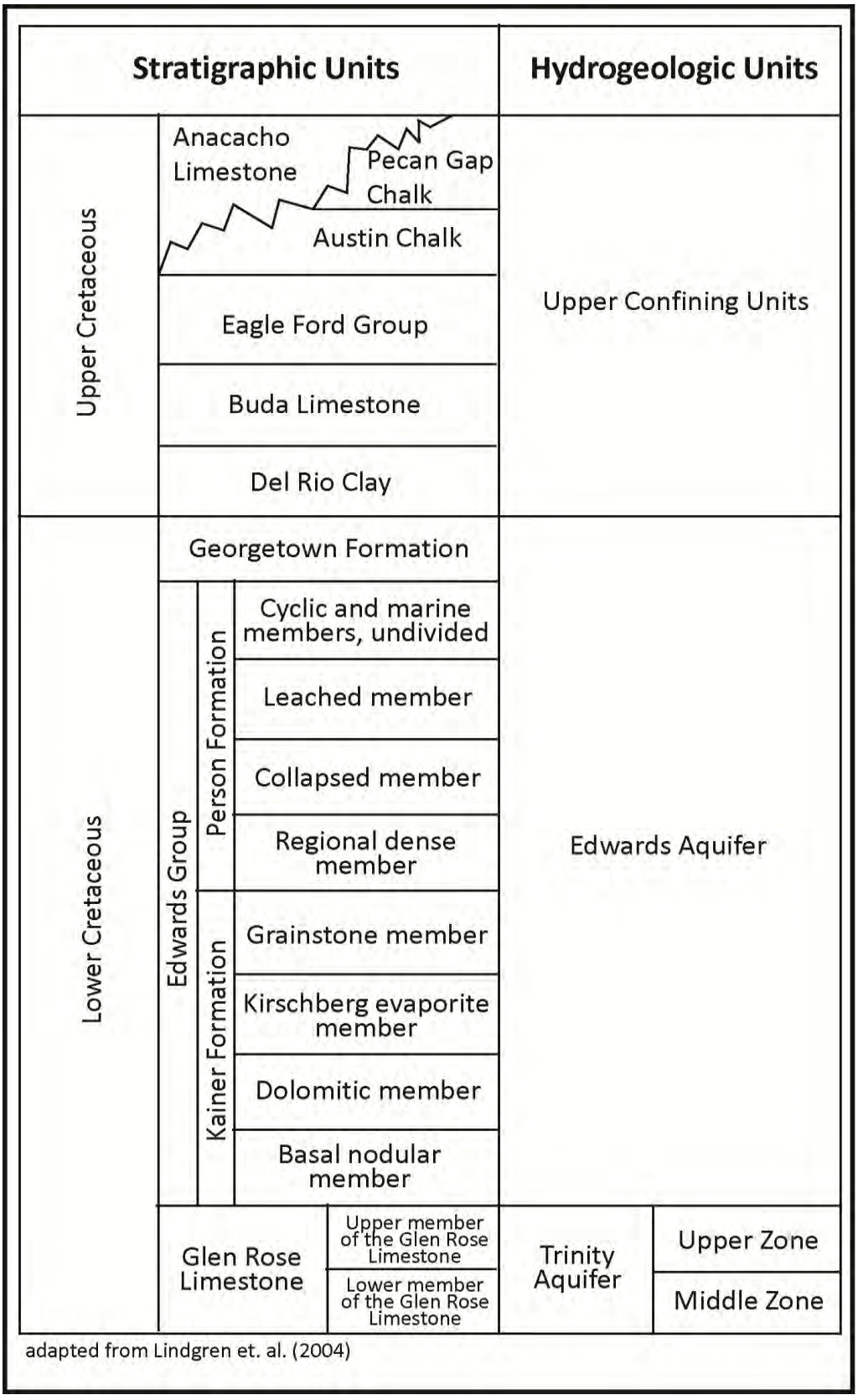
1.1. EDWARDS AQUIFER HYDROSTRATIGRAPHY

The project corridor lies on rock comprised of limestones, clays, marls, sand, and alluvial deposits. Outcrops of more recent sediments of Quaternary alluvium and the Leona Formation are located along some drainages and low-lying areas. This sediment is a result of rocks eroded off the Balcones Escarpment and Edwards Plateau and re-deposited downstream. Much of the rest of the strata that is at the surface and subsurface in this area consists of Cretaceous age rocks. From youngest to oldest, the strata consist of the Anacacho Limestone, Pecan Gap, Austin Chalk, Eagle Ford, Buda Limestone, Del Rio Clay, Edwards Limestone, and the Glen Rose Limestone.
Groundwater Quality

The Austin Chalk is about 210 feet thick in Bexar County. The Austin Chalk is not currently recognized as a minor aquifer in the State. However, near San Antonio and to the west through Medina, Uvalde, Kinney and Val Verde Counties, the Austin Chalk can be karstified with cavern development. Some wells tap the Austin Chalk, especially west of San Antonio. The Austin Chalk host substantial springs that produce Edwards Aquifer water, such as San Antonio Springs and San Pedro Springs.

The upper confining unit for the Edwards Aquifer consists of the Eagle Ford Group, Buda Limestone, and Del Rio Clay and the lower confining unit is the upper Glen Rose Limestone. The Eagle Ford Group is undifferentiated in the project study area, and consists of flags of shale and interbedded layers of hard argillaceous limestone. The thickness of outcrops in the area is approximately 30 feet. Eagle Ford Shale is commonly mistaken for "lignite" in the subsurface by local drillers. Freshly fractured pieces can omit a petroliferous odor indicating high organic content. The Buda Limestone is a hard, dense, fine-grained, buff or light gray limestone with small, calcite-filled fractures. The Buda Limestone is distinctly nodular with a conchoidal fracture and has been described as "porcelaneous" with little primary porosity or permeability. The Del Rio Formation is a blue “sticky” clay in the subsurface, which weathers in outcrop to greenish-yellow brown clay with pyrite and gypsum. The Del Rio Clay ranges from about 40 to 50 feet thick and often has large accumulations of “rams-horn” index fossil (Ilymatogyra arietina).

Figure J-1: Stratigraphic and hydrogeologic units in cretaceous age rock



The geological formations that comprise the Edwards Aquifer, from top to bottom, consist of Georgetown Limestone, Person and Kainer. Maclay and Small (1976) divided the aquifer into eight (8) hydrogeologic units (Units I through VIII), which are based on aquifer and lithologic properties. The eight (8) units are described below.

1. *Unit I: The Georgetown Limestone Formation*. Unit I can be up to about 20 feet thick in Bexar County and unconformably overlies the Person Formation. The Georgetown Limestone can be identified by the presence of the index fossil brachiopod *Waconella wacoensis*. The Georgetown Limestone is a shaley, relatively impervious yellow limestone that is not known to yield water and sometimes can be considered part of the upper confining unit to the Edwards Aquifer.

   The Person and Kainer Formations comprise the Edwards Group (Rose, 1972) and are described below.

   The Person Formation is about 185 feet thick in northern Bexar County. The composition of the Person Formation ranges from crystalline limestone to grainstone to mudstone and is comprised of three informal hydrogeologic units: the cyclic and marine members, undivided; the leached and collapsed members, undivided; and the regional dense member.

2. *Unit II: The Cyclic and Marine Members*. Unit II is composed of mudstone to fossiliferous packstone and is approximately 85 feet thick but can be somewhat variable in thickness because of the erosional unconformity between the Person and Georgetown Formations. The cyclic member is an alternating tidal flat deposit with small collapsed breccias, and the marine member is a cross-bedded biosparite to biomicrite with chert nodules.
3. *Unit III: The Leached and Collapsed Members*. Unit III is a sequence of interbedded mudstone and grainstone intervals that form one of the more porous and permeable subdivisions of the Edwards Aquifer. The leached member is a dense, bioturbated micrite and the collapsed member is composed of several one (1) to five (5) feet thick zones of collapsed stromatilitic limestone (Rose 1972). Average thickness of the collapsed and leached members is approximately 80 feet in northern Bexar County and is characterized by two highly churned, iron stained beds separated by a more massive light colored limestone. Horizontal caverns with relatively large rooms develop in this unit.
4. Unit IV: Regional Dense Member (RDM). The bottom unit of the Person Formation is the RDM, which throughout the region has a relatively consistent thickness of 20 feet. The RDM is composed of a dense argillaceous mudstone and is easily identified in the outcrop and on a variety of geophysical logs. Most of the fractures that penetrate the RDM do not appear to be solution enlarged. Caves that breach the RDM are not enlarged but are usually vertical shafts with horizontal caverns developed above or below the RDM.

   The RDM can function as a confining unit between the upper and lower portions of the Edwards Aquifer between the Kainer and the Person Formations. However, caves, faults, and fractures may greatly reduce the vertical confining ability of the RDM. The RDM is probably not an effective barrier to lateral flow at faults because of the relatively thin 20-foot section, which causes the flow of water to circumvent the RDM because of the impermeable nature of this unit.

   The Kainer Formation has an approximate total thickness of 285 feet. The lithology of the Kainer Formation ranges from mudstone to miliolid grainstone to crystalline limestone. The Kainer is subdivided into four informal members that include the grainstone, Kirschberg evaporate, dolomitic and basal nodular members.

5. *Unit V: The Grainstone Member*. Unit V is the uppermost unit of the Kainer Formation and is approximately 55 feet thick. Unit V is composed of thick sequences of dense, tightly-cemented, miliolid grainstone. Primary matrix porosity, as measured on geophysical logs, is some of the lowest

in the Edwards Aquifer. Secondary fracture porosity accounts form the bulk of effective porosity in this aquifer unit.

6. *Unit VI: The Kirschberg Evaporite Member*. Unit VI underlies the grainstone member and is about 60 feet thick. This hydrogeologic unit consists of crystalline limestone interbedded with mudstone containing chert lenses. Collapse features are common. The porosity has been described as boxwork (Maclay and Small, 1976) because of the configuration of the voids and the secondary neospar and travertine deposits. The boxwork porosity does not seem to be prevalent throughout the entire thickness or extent of Unit VI, but occurs sporadically within more massive limestone. Dissolution of evaporite minerals, such as gypsum and anhydrite, and the existence of contorted beds in the Kirschberg evaporite results in extensive secondary porosity, which creates one of the most permeable subdivisions in the Edwards Aquifer.
7. *Unit VII: The Dolomitic Member*. Unit VII is a dense, crystalline limestone with interbedded grainstone and burrowed mudstone with some chert beds. The dolomitic member has a total thickness of about 110 feet and is characterized by massive thick beds. Effective porosity and probable pathways of water in this unit are restricted to solution enlarged bedding planes, joints, fractures and faults.
8. *Unit VIII: The Basal Nodular Member*. Unit VIII is the lowermost unit of the Edwards Group and is about 50 to 60 feet of tan, marly, nodular limestone. In the subsurface, the basal nodular member has negligible porosity and permeability (Maclay and Small, 1984), and can function as part of the lower confining unit. However, in outcrop, the basal nodular member often displays extensive karstification, which has generated secondary porosity in the form of large lateral caves.

The upper Glen Rose Limestone Formation (upper Trinity Aquifer) acts as the lower confining unit for the Edwards Aquifer. The interbedded clays in the upper Glen Rose Limestone Formation are restrictive to vertical flow and act to confine water in the Edwards Aquifer. The Trinity Aquifer is an aquifer system that is composed of individual smaller layered aquifers within the geologic formations that comprise the Cretaceous age Trinity Group. The Trinity Group's deposits include sands, limestones, shales and clays that were deposited before the Edwards Limestone and, where present, are found beneath the Edwards Aquifer. The Trinity Group is divided into two formations, identified in order from the shallowest to deepest: (1) the Glen Rose Limestone Formation and (2) the Travis Peak Formation (also known as the Pearsall Formation in Stricklin and others, 1971).

The Glen Rose Limestone Formation has been divided informally into two members: (1) upper and (2) lower. The Travis Peak Formation, of the lower Cretaceous, is subdivided into five members, identified in order from shallowest to deepest: (1) Bexar Shale or Hensell Sand,(2) Cow Creek Limestone, (3) Hammett Shale, (4) Sligo Limestone, and (5) Hosston Sand. The Glen Rose Limestone Formation and the Travis Peak Formation are described below.

The upper member of the Glen Rose Limestone Formation is an alternating sequence of limestone and marly clay that, when weathered, creates the distinctive "stair-step" topography found throughout much of the Hill Country. The upper Glen Rose Limestone Formation member weathers to a yellowish-brown and develops characteristic yellowish tan soils, in contrast with the Edwards outcrop soils of grayish black.

In northern Bexar County, the upper Glen Rose Limestone Formation member is up to 500 feet thick and contains two prominent evaporite beds. Each bed ranges from 20 to 30 feet thick and is composed of yellow marl, dolomite, and white chalky limestone (Reeves 1967). Irregular bedding may be present from the removal of anhydrite and gypsum by solutioning. Springs and seeps are often located along outcrops of the evaporite beds. The upper Glen Rose Limestone Formation member yields small quantities of water to wells and the water is often of poor quality (Reeves 1967). Because of the presence of gypsum and anhydrite found near the middle and bottom of the upper Glen Rose Limestone Formation, the evaporite beds produce water with high sulfate and total dissolved solids content. Permeability and water quality can be better in areas with solution enlarged fractures or faults.

Clark (2003 and 2009) has divided the upper Glen Rose Limestone Formation into five (5) hydrogeologic intervals (A through E). The cavernous hydrostratigraphic member (interval A) is the youngest, approximately 120 feet thick, formed by alternating and interfingering mudstone, wackestone and packstone, and is well karstified. It overlies the Camp Bullis hydrostratigraphic member (interval B), which ranges from 120 to 150 feet thick. The Camp Bullis member is lithologically similar to the cavernous member, but has less karst development and consequently has a lower permeability. The upper evaporate hydrostratigraphic member (interval C) is 10 to 20 feet thick. This thin layer of highly soluble carbonates and evaporites is characterized by breccia porosity, boxwork permeability and collapse structures. Groundwater flows horizontally along this layer and usually discharges in small ephemeral springs where the interval intersects the ground surface. The fossiliferous hydrostratigraphic member (interval D) is 135-180 feet thick. Overall, it has low porosity and permeability, with the exception of a caprinid biostrome near the top of the interval. This biostrome is up to 40 feet thick, is well karstified, and hosts locally important flow systems, although the ultimate destination of this groundwater is not well known. The biostrome is thickest in the center of Camp Bullis, and thins to the north. The lower evaporate hydrostragraphic member (interval E); is quite similar to the upper evaporate member (interval C), and is 10 to 20 feet thick with mostly dissolved evaporites diverting groundwater horizontally.

The lower member of the Glen Rose Limestone Formation is about 300 to 320 feet of massively bedded dolomitic limestone with occasional rudistid reef mounds. The lower member can be well karstified and highly permeable, with substantial recharge features formed when exposed at the surface as can be seen along Cibolo Creek.

The Bexar Shale (of the Travis Peak Formation) is a deeper water transitional formation from the more terrigenous Hensell Sand that can be found further to the north in Central Texas. The Bexar Shale is up to 80 to 90 feet thick in northern Bexar County and generally consists of clays, silts and sands. This unit can produce water from the sandier sections in some locations. Below the Bexar Shale is about 80 feet of Cow Creek limestone. The bottom portion of the Cow Creek transitions to a more clay-rich shaley limestone. The upper third of the Cow Creek is usually cream colored and is more porous and permeable, which forms the base of the production for the middle Trinity Aquifer.

Below the Cow Creek, the Hammett Shale (sometimes referred to as the Pine Island Shale) is about 50 feet of "sticky" blue clay that is relatively impermeable and acts as a confining bed that divides the producing units of the lower and middle Trinity Aquifer. The lower Trinity Aquifer consists of about 100 feet or less thickness of Sligo Limestone and about 100 to 200 feet thickness of the Hosston Sand at the base of the Trinity Group. The Hosston is composed of clays, silts, sands and a basal conglomerate.

In the immediate area of the US 281 project corridor, both limestones from the Edwards and Trinity Aquifers are crossed. Within the southern extent of the zone, the proposed US 281 project lies on the Leached and Collapsed Member (Unit III) of the Person Formation. As US 281 extends northward, a fault is crossed.

1.2. TRINITY AQUIFER HYDROSTRATIGRAPHY

Based on their hydrologic relationships, the water-bearing rocks of the Trinity Group (collectively referred to as the Trinity Group Aquifer), are organized into the following aquifer units (Ashworth 1983):

- Upper Trinity: Consists of the upper Glen Rose Limestone Formation.
- Middle Trinity: Consists of the lower member of the Glen Rose Limestone Formation and the Bexar Shale/Hensell Sand and Cow Creek Limestone members of the Travis Peak Formation.
- Lower Trinity: Consists of the Hosston Sand and Sligo Limestone members of the Travis Peak Formation.

Both the Cow Creek Limestone member and the Glen Rose Limestone Formation contain caves and karst features (Veni 1997). Because of fractures, faults and other hydrogeologic factors, the upper, middle, and lower Trinity Aquifer units often are in hydraulic communication with one another and collectively should be considered a leaky-aquifer system.

The upper and middle Trinity Aquifer units are divided because of water-quality differences. This portion of the Glen Rose Limestone Formation is characterized with substantial secondary porosity and in certain areas can have cavern development. The lower Glen Rose Limestone Formation forms the upper portion of the productive middle Trinity Aquifer. The middle Trinity Aquifer is the most productive groundwater producer for the Trinity section in northern Bexar County.

Much of the water in the lower Trinity Aquifer is produced from coarser sediments in and near the bottom of the Hosston Sand. The lower Trinity Aquifer is extensively used further to the north, but few wells tap the deeper lower Trinity Aquifer in Bexar County and those few that do, generally have encountered higher total dissolved solids and poorer water quality.